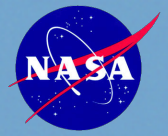
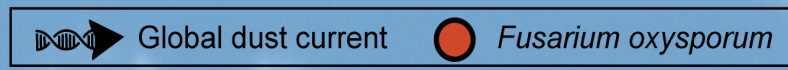
Soilborne plant pathogen dispersal and assessment: Building a remote sensing-based global surveillance system for plant disease

Katie Gold, Cornell University

Rocio Calderón, Hannah Brodsky, Jaclyn Eller (CSUN), Andrew Miles (PSU), Natalie Mahowald, Sharifa Crandall (PSU), and Ryan Pavlick (JPL)

NASA ROSES Interdisciplinary Sciences Grant #80NSSC20K1533





Science

POLICY FORUM | FOOD SECURITY

A global surveillance system for crop diseases

M. Carvajal-Yepes[1], K. Cardwell[2], A. Nelson[3], K. A. Garrett[4], B. Giovani[5], D. G. O. Saunders[6], S. Kamoun[7],...

+ See all authors and affiliations

Science 28 Jun 2019:
Vol. 364, Issue 6447, pp. 1237-1239
DOI: 10.1126/science.aaw1572

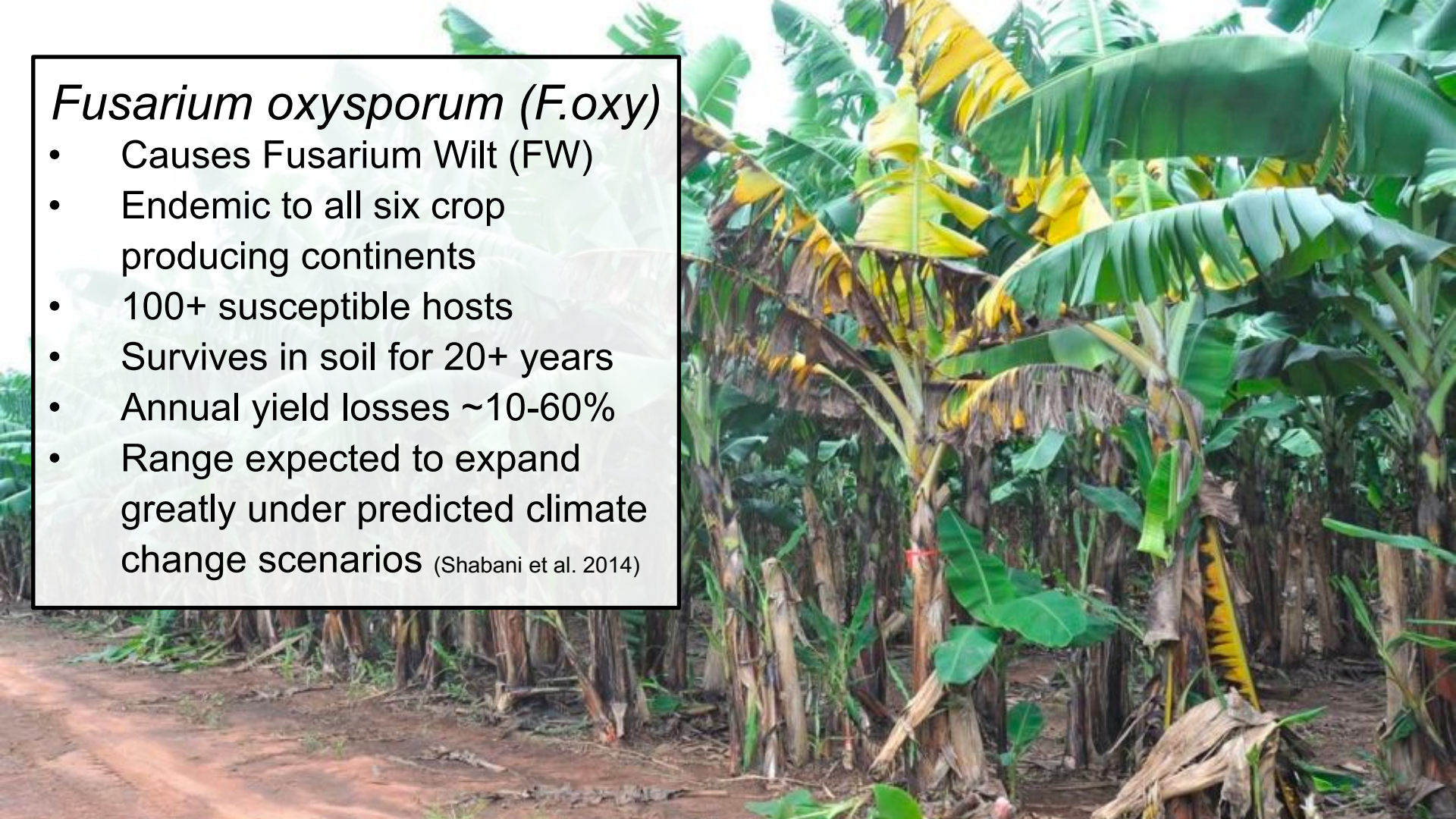
No remote sensing!

Disease causes 15-30% yield loss annually: **$220 billion lost**

>1.1 billion pounds of pesticide usage annually in US alone

Pesticides critical for modern agriculture, but overuse threatens biodiversity

Fusarium Wilt of Tomato

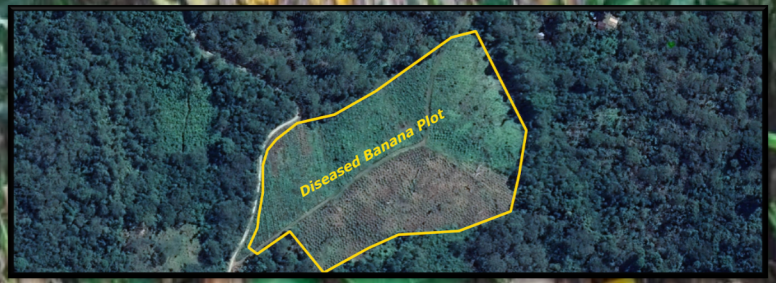


Fusarium oxysporum (F.oxy)

- Causes Fusarium Wilt (FW)
- Endemic to all six crop producing continents
- 100+ susceptible hosts
- Survives in soil for 20+ years
- Annual yield losses ~10-60%
- Range expected to expand greatly under predicted climate change scenarios (Shabani et al. 2014)

Fusarium oxysporum (F.oxy)

- Causes Fusarium Wilt (FW)
- Endemic to all six crop producing continents
- 100+ susceptible hosts
- Survives in soil for 20+ years
- Annual yield losses ~10-60%
- Range expected to expand greatly under predicted climate change scenarios (Shabani et al. 2014)

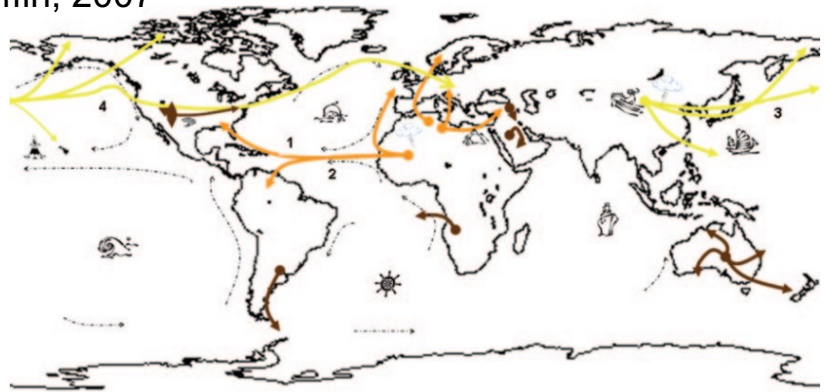


Fusarium oxysporum (F.oxy)

- Causes Fusarium Wilt (FW)
- Endemic to all six crop producing continents
- 100+ susceptible hosts
- Survives in soil for 20+ years
- Annual yield losses ~10-60%
- Range expected to expand greatly under predicted climate change scenarios (Shabani et al. 2014)

Preserving existing agroecosystems is critical to preserving natural ecosystems and global biodiversity

Griffin, 2007



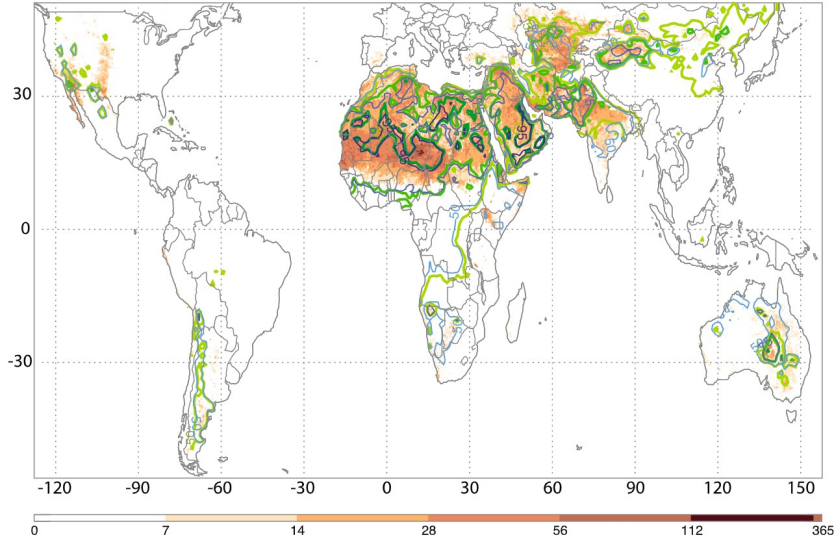
Soil dwelling fungi are capable of aerosolization and transport in global dust plumes.

Griffin 2001, Kellogg 2004, Barberan 2015

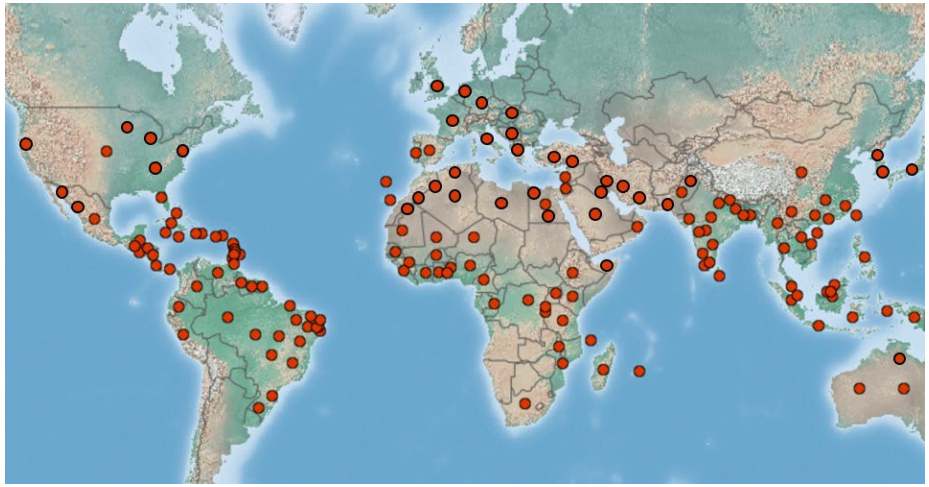
Infectious *F.oxy* spores and DNA have been isolated from North African and Asian dust samples.

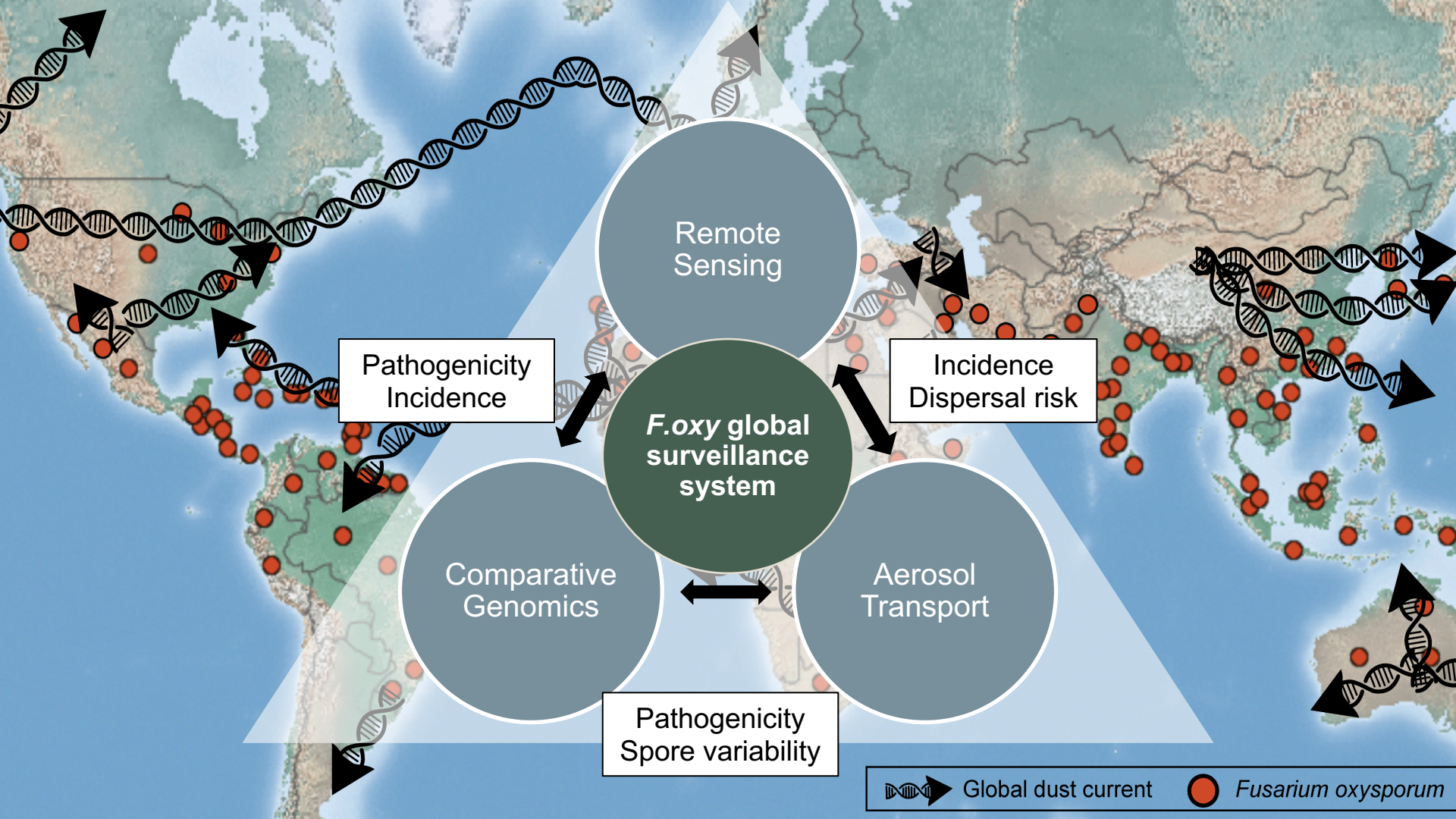
Yeo & Kim 2002, Palmero 2011, Giongo 2013, Gonzalez-Martin 2014

Ginoux et al. 2012



CABI, 2019

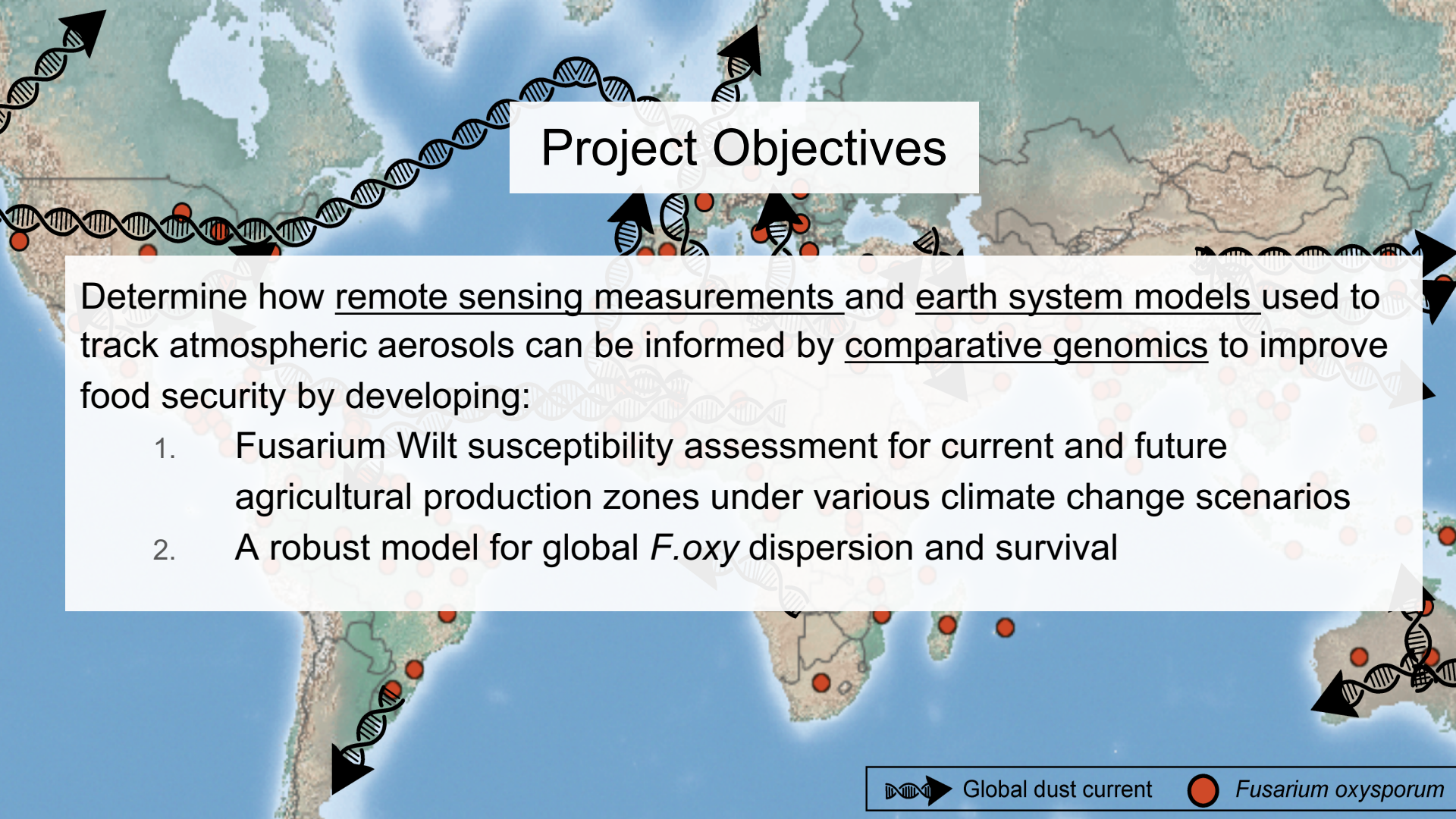


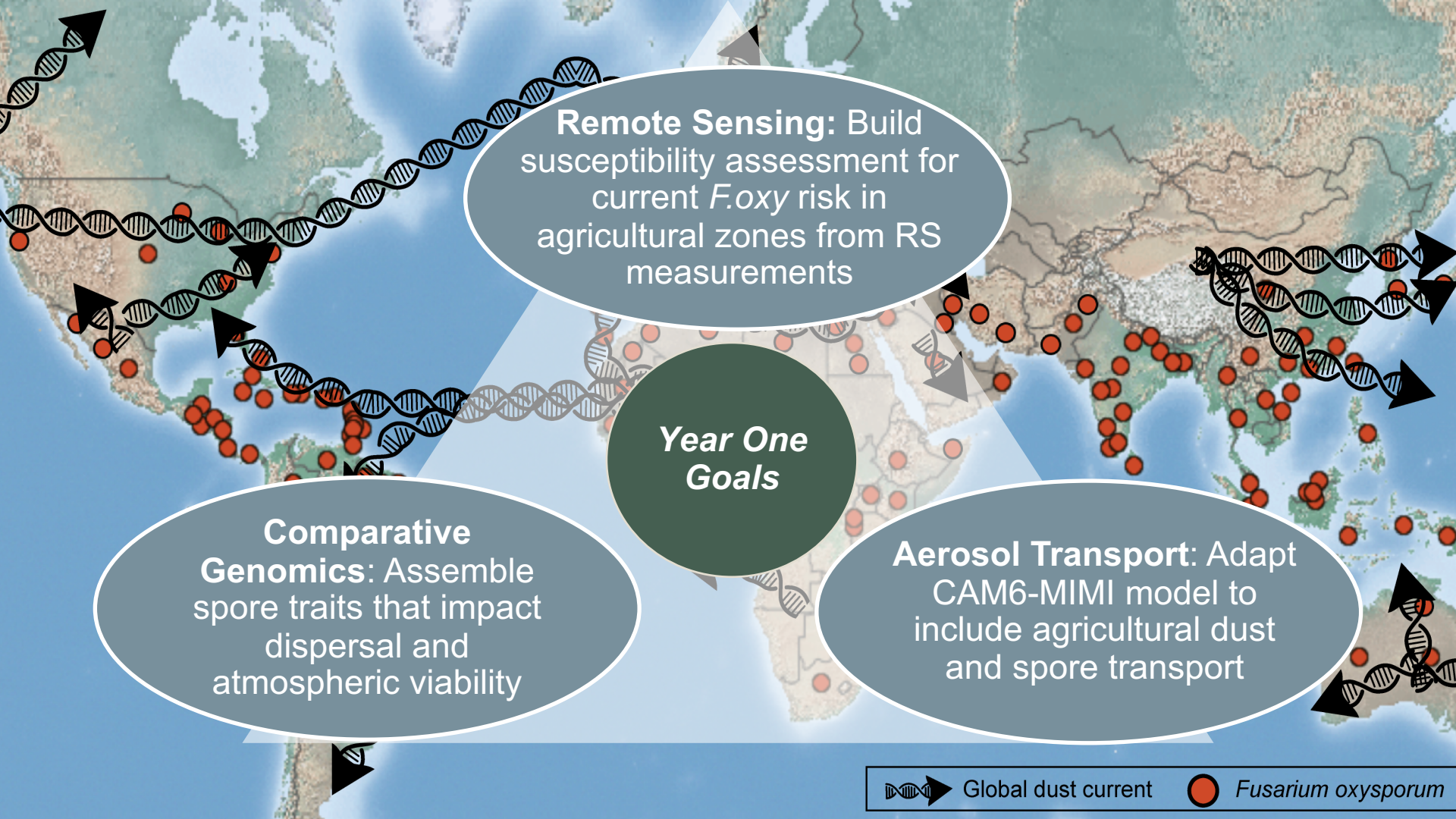

Remote Sensing
Pathogenicity Incidence
Incidence Dispersal risk
F.oxy global surveillance system
Comparative Genomics
Aerosol Transport
Pathogenicity Spore variability
Global dust current
Fusarium oxysporum

Project Objectives

Determine how remote sensing measurements and earth system models used to track atmospheric aerosols can be informed by comparative genomics to improve food security by developing:

1. Fusarium Wilt susceptibility assessment for current and future agricultural production zones under various climate change scenarios
2. A robust model for global *F.oxy* dispersion and survival

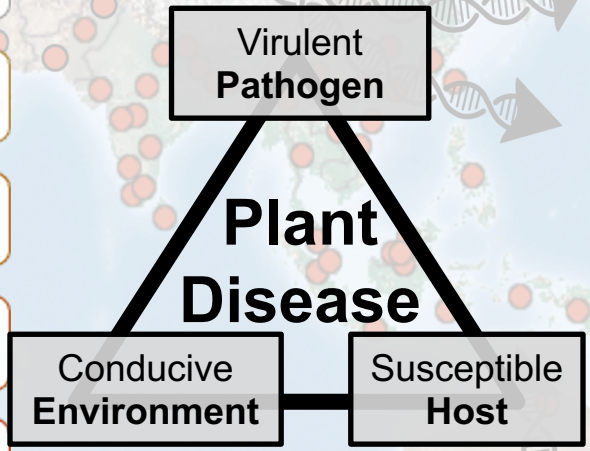



Remote Sensing: Build susceptibility assessment for current *F.oxy* risk in agricultural zones from RS measurements
Year One Goals
Comparative Genomics: Assemble spore traits that impact dispersal and atmospheric viability
Aerosol Transport: Adapt CAM6-MIMI model to include agricultural dust and spore transport
Global dust current
Fusarium oxysporum

Susceptibility Assessment

Jaclyn Eller | Rocio Calderón

1. Global **pathogen** distribution
2. Global **cropland** mapping
3. **Conducive** plant disease **environment**
4. **Dust source regions** modeling
5. **Concordance evaluation**: incidence locations vs. modeled source regions



Global dust current *Fusarium oxysporum*

Susceptibility Assessment

Rocio Calderón

1. Global **pathogen** distribution
2. Global **cropland** mapping — HARVEST; NASA Harmonized Landsat Sentinel-2
3. **Conducive** plant disease **environment** — MODIS Moderate Resolution Imaging Spectroradiometer; SMAP Soil Moisture Mapping; GPM NASA • JAXA Global Precipitation Measurement
4. **Dust source regions** modeling
5. **Concordance evaluation**: incidence locations vs. modeled source regions

Ryan Pavlick

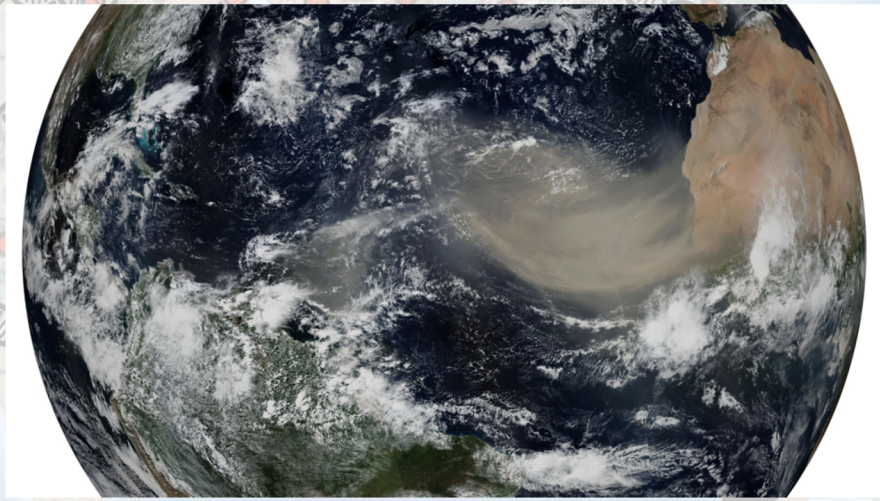
Global dust current *Fusarium oxysporum*

Aerosol Transport: CESM CAM6-MIMI

Hannah Brodsky

Natalie Mahowald

- Community Earth System Model (CESM)
  - Earth System Model linking land, ocean, atmosphere, and ice models
- Community Atmosphere Model (CAM6)
  - State of the art climate model, can simulate weather events
  - Includes: dust, sea salts, sulfates, soot, and organic carbon aerosols
- MIMI framework
  - MIMI = Mechanisms of Intermediate Complexity for Modelling Iron
  - Aerosol processing framework, makes it easy to simulate spore viability during transport



Global dust current

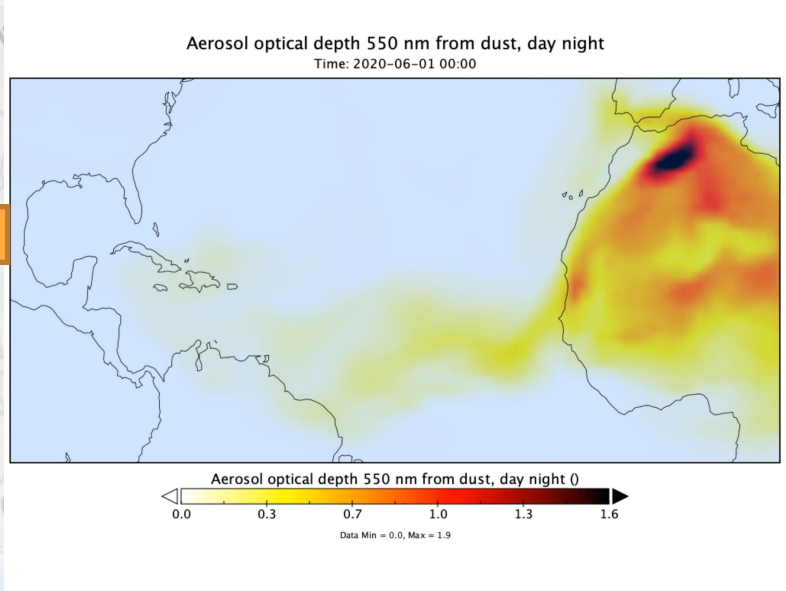
Fusarium oxysporum

Incorporating ag dust and spores

Hannah Brodsky

Natalie Mahowald

1. **Compare CAM6-MIMI to observations**
2. **Incorporate ag dust into model**
3. Incorporate spores into model
4. Kill spores during transport
5. Spore differentiation by region
6. Run the model from 1980-2020



Global dust current

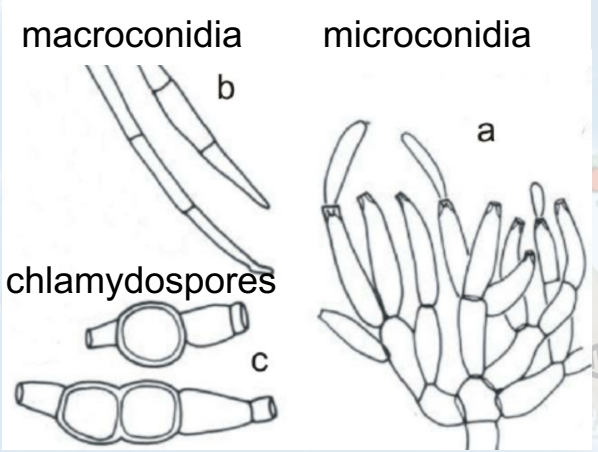
Fusarium oxysporum

Spore traits that influence dispersal and atmospheric survival

Andrew Miles

Sharifa Crandall

Spore Type	Spore Information	Reference
Ciceris	Chlamydospore diameter 4.8-8.1 µm; Microconidia size 5.1-12.8 x 2.5-5.0 µm; Macroconidia 16.5-37.9 x 4.0-5.9 µm	Arvayo-Ortiz et al., 2011; Dubey et al., 2010
General	average ascospore size: 21 um x 3.5 µm; 19–24 x 3–4 µm and macroconidia as 25–50 x 3–4 µm	Booth, 1971; Trail et al., 2002
General	long-distance ascospore dispersal will not be effective at relative humidity less than 50 %	Beyer et al., 2005
General	Gravitational settling of 1-2 mm per s-1 in still air	Keller et al., 2014



Global dust current

Fusarium oxysporum

Next Steps

Remote Sensing: Map and integrate host and conducive environment range into susceptibility assessment

Compare relatedness between source/sink isolates

Looking forward:

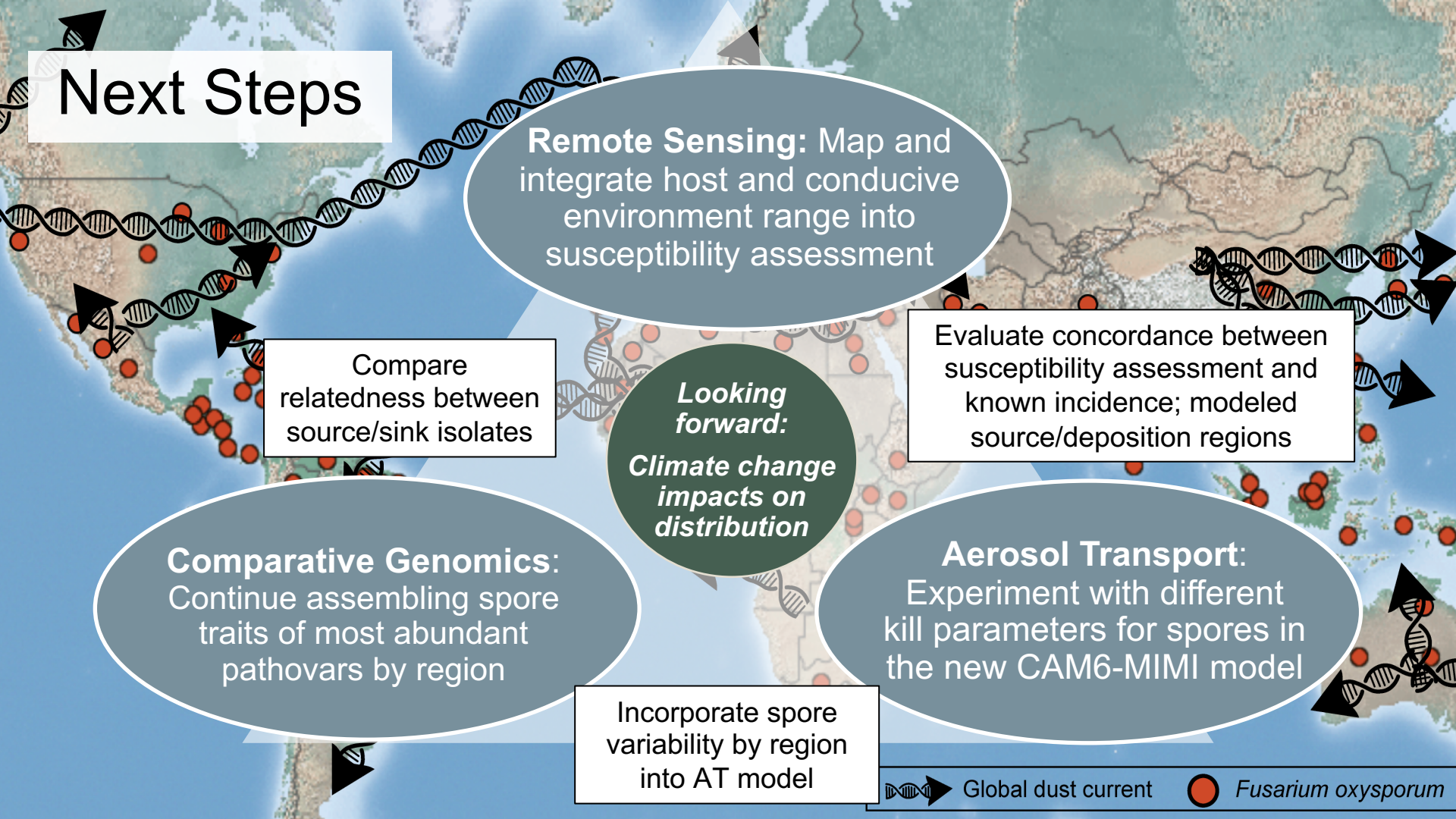
Climate change impacts on distribution

Evaluate concordance between susceptibility assessment and known incidence; modeled source/deposition regions

Comparative Genomics: Continue assembling spore traits of most abundant pathovars by region

Aerosol Transport: Experiment with different kill parameters for spores in the new CAM6-MIMI model

Incorporate spore variability by region into AT model



Interested in more plant disease remote sensing?

Visit Fernando Romero Galvan's NASA FINESST poster breakout room this afternoon!

Questions?

kg557@cornell.edu

Twitter @KaitlinMGold

blogs.cornell.edu/goldlab

#80NSSC20K1533

Jet Propulsion Laboratory

Global dust current

Fusarium oxysporum